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Registration of 20 GEM Maize Breeding Germplasm Lines Adapted to the Southern USA

Twenty maize (*Zea mays* L.) breeding germplasm lines have been developed cooperatively by the USDA GEM (Germplasm Enhancement of Maize) project (Reg no. GP-407 to GP-426, PI 639037 to PI 639056). The GEM project is a cooperative research effort to facilitate the introduction of exotic maize germplasm into U.S. breeding programs. It involves most of the larger private U.S. maize breeding companies and many public cooperators (Salhuana et al., 1994; Pollak and Salhuana, 2001; Goodman, 1999; Goodman and Carson, 2000; Goodman et al., 2000). Replicated breeding trials coordinated by North Carolina State University as part of the GEM project, and conducted by several public and private maize breeding programs, have identified 20 superior F_2S_2 germplasm lines containing 50% tropical germplasm by pedigree (Table 1). When topcrossed to sister-line crosses or foundation-seed inbreds, these germplasm lines yielded well in North Carolina and other southern corn growing regions of the United States in comparison to commercial check hybrids.

The sources of the tropical germplasm involved in these germplasm lines include hybrids from Brazil (DKXL370A and DKXL380), Mexico (DKB830), and Thailand (DK212T and DK888). These hybrids were contributed to the GEM project by Bruce Maunder (retired vice-president of Dekalb Agricultural Research). The U.S. parents were privately owned inbred lines of the stiff stalk heterotic group. Germplasm lines were developed by selfing and selecting variable F_1s from tropical source × U.S. inbred crosses in North Carolina under standard nursery conditions, followed by a second selfing–selection season in Homestead, FL (F_2S_1), and a third selfing–selection season in a selection nursery in Raleigh (F_2S_2). All procedures were performed using ear-to-row methods, except that F_2 seeds planted in Homestead were bulked by pedigree (i.e., all the F_2 seed from each tropical source × U.S. inbred were bulked). Germplasm lines were visually selected on the basis of resistance to a mixture of foliar diseases, resistance to Fusarium ear rot [caused by *Fusarium verticillioides* (Sacc.) Nirenberg (synonym *F. moniliforme* Sheldon) (teleomorph: *Gibberella moniliformis*) and *F. proliferatum* (Matsushima) Nirenberg (teleomorph: *G. intermedia*)], resistance to anthracnose stalk rot (caused by *Colletotrichum graminicola* G.W. Wils), resistance to lodging, early flowering, synchrony of silk and pollen production, and reduced plant and ear height.

All diseases were artificially inoculated. Foliar diseases were inoculated by sprinkling dry inoculum for a mixture of diseases {southern and northern leaf blight [caused by *Bipolaris maydis* (Nisikado & Miyake) Shoemaker = *Helminthosporium maydis* Nisikado & Miyake and *Exserohilum turcicum* (Pass.) K. J. Leonard & E. G. Suggs = *Helminthosporium turcicum* Pass., respectively], anthracnose leaf blight (caused by *Colletotrichum graminicola*), gray leaf spot (caused by *Cercospora zeae-maydis* Tehon & E.Y. Daniels)} into the whorl at about 7 wk after planting. Ear and stalk rots were inoculated mechanically by puncturing the ear and stem respectively with toothpicks and needles, respectively, bearing inoculum. Foliar and plant diseases were rated at least twice during each season on an individual plant basis. Additionally, plot ratings were taken for foliar disease approximately 3 wk after pollinations ended. Foliar disease was rated on a one to nine scale with nine being no symptoms and one being dead. Plants rated four or below were discarded. Plants that were killed by stalk rot were discarded. Ear rot was rated at the time of harvest. Ears that had significant amounts of visible rot were discarded.

Topcross seed for initial yield trials was produced using LH185 and the sister line cross FR697 × FR615 as testers. The released germplasm lines were among the top performers out of approximately 2000 germplasm lines tested, based on data from a minimum of 15 test locations from Delaware to Georgia and as far west as Missouri over 2 yr (1997 and 1998). In these tests, seed moisture was comparable to, or lower than, the commercial hybrid check means in all cases and lodging was similar to that of the hybrid checks for all the germplasm lines. The top yielding germplasm lines in the initial trials using LH185 as tester were GEMS-0012 and GEMS-0019, which yielded 10 167 kg ha^{-1} and 10 262 kg ha^{-1}, respectively, compared to a check mean of several elite commercial hybrids of 9357 kg ha^{-1} (the yields of the individual checks were: DK683, 9816 kg ha^{-1}; DK689, 9442 kg ha^{-1}; DK714, 9863 kg ha^{-1}; DK743, 10 370 kg ha^{-1}; LH132 × LH51, 8687 kg ha^{-1}; P3165, 9552 kg ha^{-1}; P32K61, 9957 kg ha^{-1}).

Additional yield experiments, at several locations throughout the southern corn belt in 2001 and 2002 with topcross seed produced using LH287 and LH185Bt as testers, provided head-to-head comparisons across several Lancaster-type testers and confirmed that these germplasm lines performed well compared to elite hybrid checks, in most cases out-yielding the checks (Goodman 2002; also see the GEM website, www.public.iastate.edu/~usda-gem/Yield_Trial_Data/Year_2002/Year_2002_NC/Pubwin.txt, verified 27 Nov. 2005). In these trials GEMS-0012 was again the top yielding germplasm line. With LH287 as tester, it yielded 10 861 kg ha^{-1}, compared to the check mean of 9390 kg ha^{-1} [The top yielding check, LH200 × LH62, yielded 10 266 kg ha^{-1}. Other checks were DK687, 9519 kg ha^{-1}; LH132 × LH51, 8907 kg ha^{-1}; NC320 × (LH132 × LH51), 9772 kg ha^{-1}; P30F33, 6976 kg ha^{-1}; P3165, 9389 kg ha^{-1}; and P32K61, 9473 kg ha^{-1}]. Table 1 shows the results of the trials conducted using LH185Bt as tester.

In yield trials performed in the midwestern corn belt (Iowa, Missouri, and Illinois) using LH283 and LH185 as testers, the yields of all of these germplasm lines were inferior to the elite hybrid check means. GEMS-0018, GEMS-0015, GEMS-0009, and GEMS-0021 yielded the best of these germplasm lines in top crosses with LH185. GEMS-0018, GEMS-0013, and GEMS-0009 yielded best in topcrosses with LH283. In these tests, lodging for several germplasm lines was somewhat greater than the hybrid checks (see experiments 03609 and 036010 at www.public.iastate.edu/~usda-gem/Yield_Trial_Data/Year_2003/YT_2003.html; verified 1 Dec. 2005).

The germplasm lines have a range of kernel colors; orange and yellow (GEMS-0006 and GEMS-0020), orange (GEMS-0010, GEMS-0012, GEMS-0013, GEMS-0018, and GEMS-0031), yellow and white (GEMS-0024), and yellow (all others). A range of kernel textures is also found; semiflint to semident (GEMS-0030, GEMS-0005 GEMS-0009, GEMS-0011, GEMS-0010, GEMS-0006, GEMS-0017, and GEMS-0013), semiflint (GEMS-0019 and GEMS-0023) and semident (all others). These data can be found by querying the database found on the GRIN website (www.ars-grin.gov/npgs/acc/acc_queries.html; verified 27 Nov. 2005).

Flowering of germplasm lines per se occurred between 3 and 24 d later than B73 in Ames, IA, in 2003. Flowering time observations made in 2002 were highly correlated with the 2003 flowering data, but with a smaller range of between 2 and 15 d later than B73. The earliest flowering were GEMS-0029 and GEMS-0010 (4 and 5 d later than B73 in 2003; 2 and 3 d later in 2002). In Clayton, NC, in 1999, flowering times for the GEM germplasm lines were 1 to 14 d later than B73 with GEMS-0009, -0010, -0018, and -0021 all flowering within 1 or 2 d of B73.

Table 1. The GEM ID numbers and PI numbers of the 20 germplasm lines registered with their corresponding original identifiers. Yield and moisture data are shown from yield trials conducted in 2001 and 2002 with topcross seed produced using LH185Bt as the tester. GEMS-0023, -0030, and -0031 were not included in this yield trial but yielded well in other associated trials.

PI numbers	GEM Number	Original Identifier	Yield	Moisture
			kg ha^{-1}	g kg^{-1}
639037	GEMS-0004	2084–02_DK212T_S11_F2S4_9151-Blk38/00	12416	186
639038	GEMS-0005	2086–01_DK212T_S11_F2S4_9154-Blk20/00	12811	205
639039	GEMS-0006	2088–01_DK212T_S11_F2S4_9157-Blk29/00	12579	192
639040	GEMS-0009	2111–01_DK212T_S11_F2S4_9166-Blk31/00	11831	193
639041	GEMS-0010	2112–02_DK212T_S11_F2S4_9169-Blk20/00	11197	186
639042	GEMS-0011	2116–02_DK212T_S11_F2S4_9172-Blk28/00	11612	196
639043	GEMS-0012	2120–01_DK888_S11_F2S4_9175-Blk28/00	13596	207
639044	GEMS-0013	2121–04_DK888_S11_F2S4_9178-Blk29/00	13163	205
639045	GEMS-0015	2131–01_DK888_S11_F2S4_9184-Blk20/00	13452	205
639046	GEMS-0017	2142–01_DK888_S11_F2S4_9190-Blk19/00	11775	197
639047	GEMS-0018	2143–02_DK888_S11_F2S4_9193-Blk19/00	12246	201
639048	GEMS-0019	2146–01_DK888_S11_F2S4_9196-Blk29/00	13294	208
639049	GEMS-0020	2150–01_DK888_S11_F2S4_9199-Blk16/00	12020	212
639050	GEMS-0021	2152–02_DK888_S11_F2S4_65/97_Bulk/97–99	11951	196
639051	GEMS-0023	2156–02_DK888_S11_F2S4_H92847-Blk13/00	–	–
639052	GEMS-0024	2201–01_DKB830_S11_F2S4_9208-Blk27/00	12127	189
639053	GEMS-0028	2250–02_DKXL370A_S11_F2S4_3363-Blk03/00	11229	185
639054	GEMS-0029	2253–01_DKXL370A_S11_F2S4_9220-Blk24/00	12007	191
639055	GEMS-0030	2258–03_DKXL380_S11_F2S4_71/97_Bulk/98	–	–
639056	GEMS-0031	2282–01_DKXL380_S11_F2S4_9226-Blk26/00	–	–
		Check mean†	11009	190

† GEM's protocol is to compare performance relative to the means widely used commercial checks. The top yielding check, LH200 × LH185Bt yielded 11656 kg ha^{-1}. Other checks were FR1064 × LH185Bt (10613 kg ha^{-1}) and LH198 × LH185Bt (10764 kg ha^{-1}).

Preliminary observations were made regarding resistance to a number of diseases: Per se germplasm lines were artificially inoculated in 2003 and 2004 in Mississippi with 3.4 mL of an *Aspergillus flavus* Link:Fr. spore suspension (10^6 spores mL^{-1}) injected through the husk of the ear, 1 wk after midsilk. GEMS-0028 and GEMS-0030 showed good resistance to *Aspergillus* ear rot and aflatoxin accumulation relative to two resistant checks, Mp313E and Tuxpan. Both GEM germplasm lines were up to 1 wk earlier than the checks and are therefore promising sources for future breeding efforts for aflatoxin resistance. GEMS-0021 was inoculated with a spore suspension of *Fusarium verticillioides* (Sacc.) Nirenberg (synonym *F. moniliforme* Sheldon) (teleomorph: *Gibberella moniliformis*) and *F. proliferatum* (Matsushima) Nirenberg (teleomorph: *G. intermedia*) injected down the silk channel in Clayton, NC, in 2003. It showed relatively good ear rot resistance (1.3% kernels rotted compared to the mean for the field of 6.35%) and resistance to fumonisin accumulation (4 mg kg^{-1} compared to 6.6 mg kg^{-1}). This was the only family tested for fumonisin resistance. Gray leaf spot trails were performed in Andrews, NC, Laurel Springs, NC, and Marion, NC, in 2000, relying on natural inoculation at Andrews and using dry inoculum sprinkled into the whorl at 7 wk after planting in Marion and Laurel Springs. Several ratings were taken through the season using a one to nine scale (see above). In hybrids with FR697 × FR615, several germplasm lines matched DK683 (a highly resistant commercial hybrid) for gray leaf spot resistance. GEMS-0020 was most resistant, with GEMS-0015 and GEMS-0018 showing some resistance. Regarding family per se performance, GEMS-0019 was the most gray leaf spot resistant, followed by GEMS-0024 and GEMS-0030. GEMS-0020 and GEMS-0028 performed acceptably, but only GEMS-0019 was as resistant as NC258, the resistant inbred check. All diseases were rated in trials with two replications for each year reported except for the aflatoxin study, which had three replications per year.

These germplasm lines provide a unique source of tropical × temperate maize germplasm for the development of lines with improved yield and potential disease resistance. They have particular utility for developing lines adapted to conditions in the southern USA. Bulked $F_2S_{2:3}$ or $F_2S_{2:4}$ seed is available from the North Central Plant Introduction Station, USDA-ARS, Iowa State University, Ames, Iowa 50011. These materials are released without restrictions of any kind.

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References

Goodman, M.M. 1999. Broadening the genetic diversity in breeding by use of exotic germplasm. p. 139–148. *In* J.G. Coors and S. Pandey (ed.) Genetics and exploitation of heterosis in crops. CSSA, Madison, WI.

Goodman, M.M. 2002. New sources of germplasm: Lines, transgenes, and breeders. p. 28–41 in J.M. Martinez R., F. Rincon S., and G. Martinez G. (ed.) Mem. Congresso Nacional de Fitogenetica, Univ. Autonimo Agr. Antonio Narro, Saltillo, Coah., Mexico.

Goodman, M.M., and M.L. Carson. 2000. Myth vs. reality: Corn breeding, exotics, and genetic engineering. Corn Sorghum Research Conference Proc., Chicago. 8–10 Dec. 2000. Am. Seed Trade Assoc., Alexandria, VA.

Goodman, M.M., J. Moreno, F. Castillo, R.N. Holley, and M.L. Carson. 2000. Using tropical maize germplasm for temperate breeding. Maydica 45:221–234.

Pollak, L.M., and W. Salhuana. 2001. The germplasm enhancement of maize (GEM) project: Private and public sector collaboration. p. 319–329. *In* H.D. Cooper, C. Spillane, and T. Hodgkin (ed.) Broadening the genetic base of crop production. CABI Publ., Wallingford, Oxon, UK.

Salhuana, W., L. Pollak, and D. Tiffany. 1994. Public/private collaboration proposed to strengthen quality and production of USA corn through germplasm enhancement. Diversity 10(1):77–78.

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